DAT328
SQL Server 2005: Index Creation Best Practices

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- Author for some SQL Server 2005 Whitepapers on MSDN (links from www.SQLskills.com)
- Coauthor MSPress: SQL Server 2000 High Availability, Presenter/Technical Manager for SQL Server 2000 High Availability DVD
- Writer/Editor for SQL Magazine www.sqlmag.com

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Overview

- Index Usage and Effective Queries
- Index Concepts
- Table Structures: Internals
- Clustered Tables: The Pros and Cons
- Non-clustered Indexes: The Pros and Cons
- Finding the Right Balance
- Adding Non-Clustered Indexes for Better Performance
- Keeping Performance Optimal

Index Usage
Conceptual

- Allows faster access to data, improving:
  - Lookup/query time
  - Insert/Update time – record location defined
  - Delete time – record location also defined
- Con: overhead for modifications
- Index Strategy Concepts
  - Fewer indexes are better than lots of indexes
  - Wider indexes have more uses
    - Can be used for point queries
    - Can be used by NARROW low selectivity queries
- Write Effective Queries to better take advantage of indexes…

Accessing Data: Limit Data

- Subset of columns = Projection
  - Do not use * (unless against view)
  - Optimizer has more chances for optimizing query when result set is NARROW (only the required columns)
- Subset of rows = Selection
  - Use positive search arguments
  - Isolate the column to one side of the expression
    - USE: MonthlySalary > *value*/12 (constant, seekable)
    - DO NOT USE: MonthlySalary * 12 > *value* (must scan)
  - Be cautious with LEADING wildcards
    - USE: LastName LIKE 'S%'
    - Try not to just append %val% to every application
- Consider using Views, Stored Procedures and Functions to limit the columns/rows

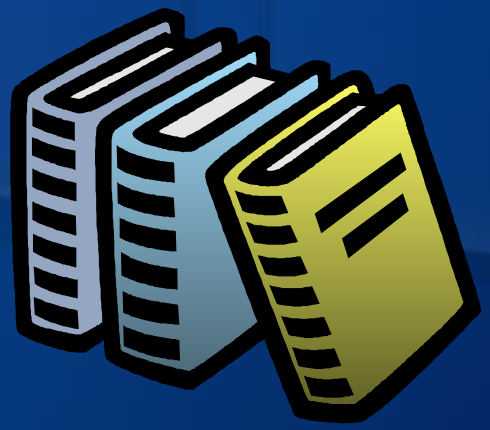
Index Concepts
Book analogy

- Think of a book—with indexes in the back
- The book has one form of logical ordering
- For references, you use the indexes in the back…to find the data in which you are interested you look up the key
- When you find the key, you must lookup the data based on its location… i.e., a “bookmark” lookup
- The bookmark always depends on the (book) content order

Index – Species Common Name

Index – Animal by Type, Name *Bird, Mammal, Reptile, etc…*

Index – Animal by Country, Name



Index – Animals by Habitat, Name *Air, Land, Water*

Index – Species Scientific Name

Index – Animal by Continent, Country, Name

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Index Concepts
Tree analogy

- If a tree were data and you were looking for leaves with a certain property, you would have two options to find that data:
- 1) Touch every leaf – interrogating each one to determine if they held that property…SCAN
- 2) If those leaves (which had that property) were grouped such that you could start at the root, move to the branch and then directly to those leaves…SEEK

Index Usage
Physical

- "Data" is stored in Index
  - Leaf level of an index (regardless of index type) stores relevant data for *every* row of the table
    - Clustered Index Leaf Level = Data
    - Non-clustered Index Leaf Level
      - Without additional "include" columns
        - Stores the NC Index KEY + the CL Key (or RID of Heap)
      - With additional "include" columns
        - Stores the NC Index KEY + additionally included columns + the CL Key (or RID of Heap)
  - Non-leaf level(s) are for navigation
- Indexes can be used to answer a query OR to help "point" to full data row to answer query

INCLUDE Non-Key Columns
New in SQL Server 2005

- Leaf level of index can include non-key columns
- Index key limited to 900 bytes/16 columns – this is to keep tree structure and non-leaf levels optimal/small
- Allows more covering indexes
- Allows LOB data types (use sparingly)
- Also, consider Indexed Views for more interesting/wider index options

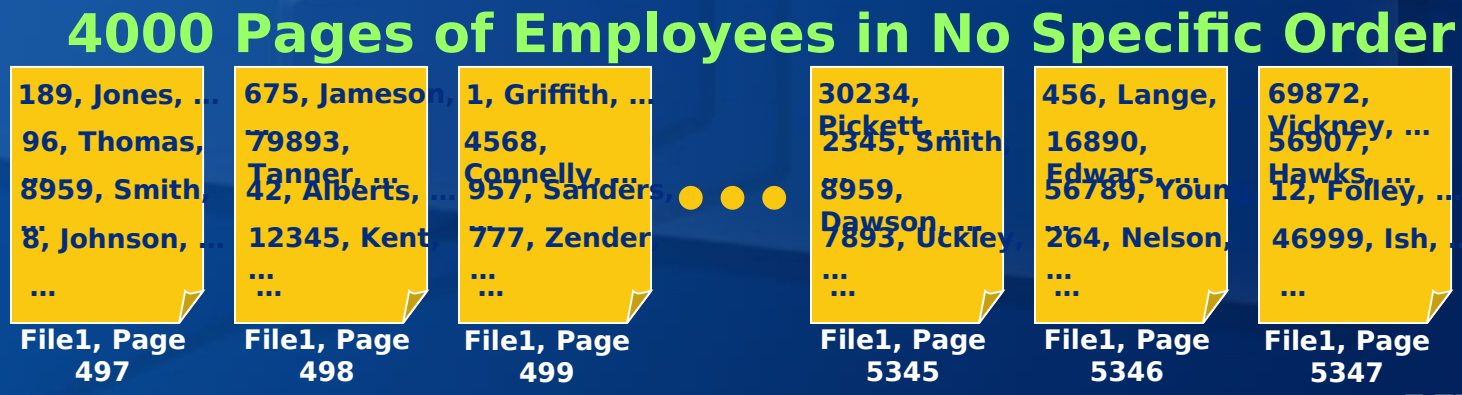
Table Structure

- HEAP: A table without a clustered index
- Clustered Table: A table with a clustered index
- Non-clustered Indexes *do not* affect the base table's structure
- However, Non-clustered Indexes are affected by whether or not the table is Clustered…

Hint: The non-clustered index dependency on the clustered index should impact your choice for the clustering key!

Table Structure: Heap

- Table without a Clustered Index
- Records are *not ordered*
- No Doubly-Linked List
- Access via Index Allocation Map (IAM)
  - IAMs = 8 K Page (Chain) which Tracks Object Usage
    - 1 - IAM per Table/Index (for inrow_data), per File, per 4 GB
- If *no* Indexes exist – a full Table Scan required
  At least 4000 I/Os on the Employee Table Heap



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Heap: Pros

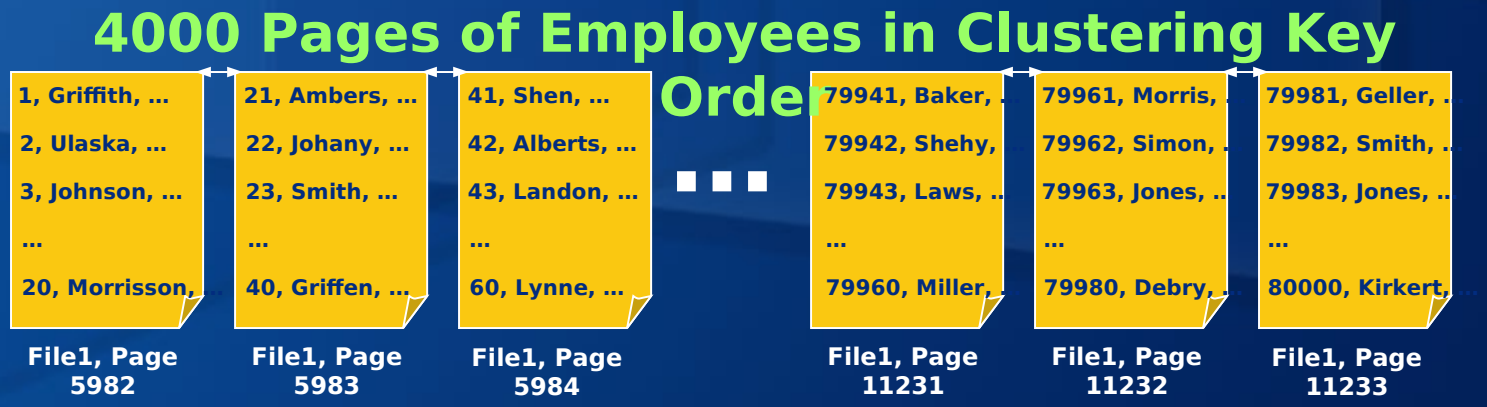
- Effective for “staging” data
  - Truncate table
  - Drop non-clustered Indexes
  - Drop CL Index
  - Load data (consider parallel bulk load)
  - Create CL Index, create non-clustered Indexes
- Excellent for “staging” data into a table that will become a partition to a partitioned table (SQL Server 2005) or to a partitioned view (SQL Server 2000)
- For more on Partitioning, read MSDN whitepaper: SQL Server 2005 Partitioned Tables http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnsql90/html/sql2k5partition.asp

Heap: Pros

- Indexes can be created after load and index creation can be parallelized
- Efficient for SCANs ONLY – when no UPDATEs (otherwise, forwarding pointers – scans become significantly less efficient)
- Space Efficient – Space from Deletes is reused on subsequent Inserts (at the cost of performance)
- Best used when table is not typical OLTP or combo OLTP/DSS table
- Forward only “logging” table

Table Structure
Clustered table

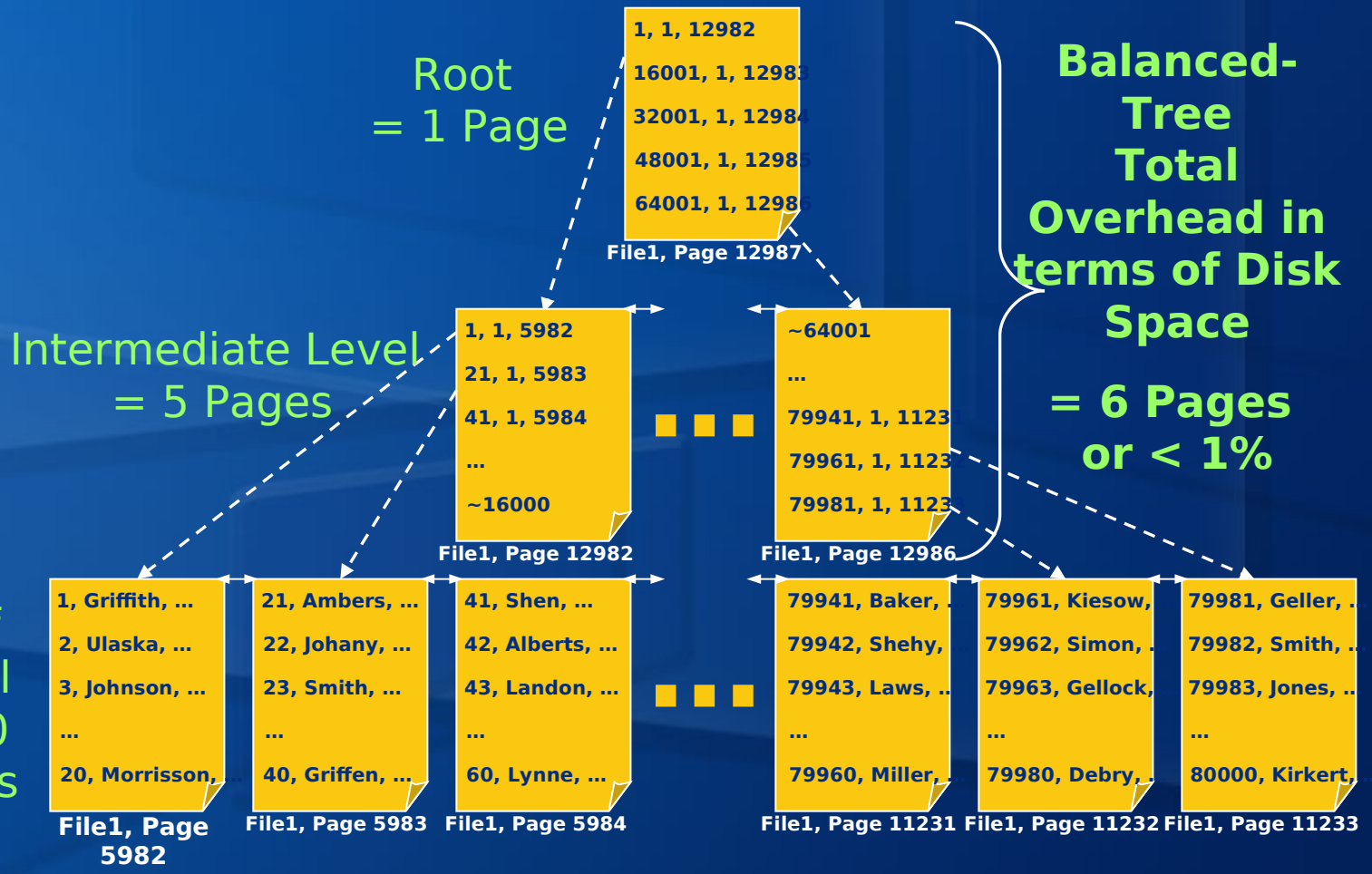
- Clustered Index defines order – applied at CREATION
- Expensive—in time and space—to build
  (an additional 1-2 times the index size for (re)build)
- Table is a doubly-linked list – order maintained LOGICALLY
- *Might* be expensive to maintain



Clustered EmployeeID

Employee Table

Consider a clustered index on an identity column (even better if this is the table's Primary Key)

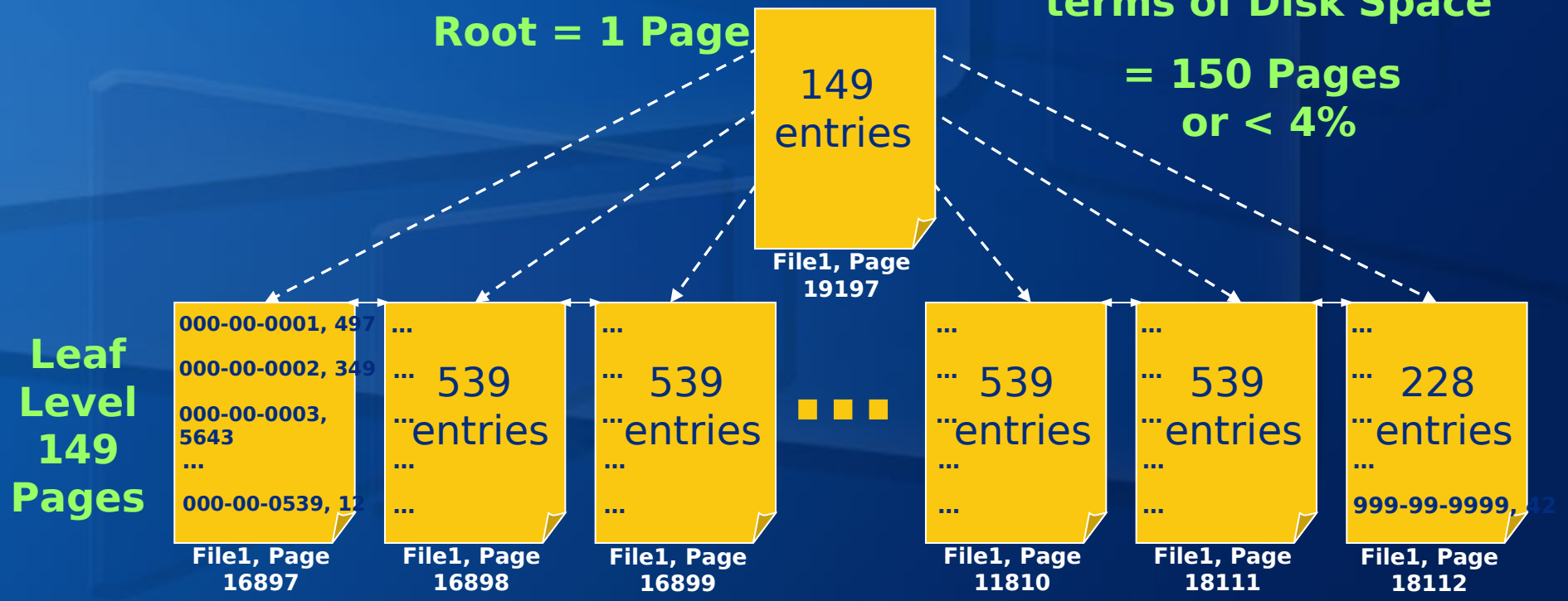


Non-Clustered Indexes
Physical

- Depend on whether the table is a Heap or Clustered
- Clustered Table
  - Rows use the Clustering Key
  - No additional OH to add this column – may use actual data to define the clustering key
  - Minimizes NC Index manipulation if rows move (the NC still points to the CL Key)
  - Clustering key should be static and narrow
- Heap
  - Generally, not recommended

Non-Clustered Index
Unique Key SSN

- Leaf level contains the non-clustered key(s) to define the order
- Also includes either the Heap's Fixed RID or the Table's Clustering Key



Clustered Index Criteria

- Unique
  - Yes – No overhead, data takes care of this criteria
  - NO – SQL Server must “uniquify” the rows on INSERT. This costs time and space. Each duplicate has a 4-byte uniquifier. In SQL Server 2000, all uniquifiers are regenerated when the CL index is rebuild. This is not true in SQL Server 2005.
- Narrow
  - Yes – Keeps the NC indexes narrow
  - NO – Possibly wastes space
- Static
  - Yes – Improves Performance
  - NO – Costly to maintain during updates to the key especially if row movement and/or splits

In fact, an identity column that’s ever-increasing is ideal…

Or date, identity can also be excellent choice – esp. in partitioned scenario

Clustering on an Identity

- Pros
  - Naturally Unique
    (although not guaranteed – should combine with key constraint)
  - Naturally Static
    (although should be enforced through permissions and/or trigger)
  - Naturally Narrow
    (only numeric values possible, whole numbers with scale = 0)
  - Naturally creates a hot spot…
    - Needed pages for INSERT already in cache
    - Minimizes cache requirements
    - Helps reduce fragmentation due to INSERTs
    - Helps improve availability by naturally needing less defrag
- Con
  - Not appropriate for extremely HIGH Insert volume (400+/sec for one table)
  - Consider a couple of hot spots instead of just one

Optimal Table Structures
Poor clustered index choice

- Worst base table structure is a poor choice for Clustered Index, for example: LastName
  - Fragmentation → poor performance
  - Non-unique → poor performance
    - Uniquifier wastes space and time
    - SQL 2000 only, rebuilding a clustered index on a non-unique clustered index forces non-clustered indexes to be rebuilt
  - Volatile → poor performance
    - Most-duplicated value
    - Could cause record relocation and therefore fragmentation
  - Wide → poor performance
    - Wastes space/time – wide keys take longer to maintain/insert.
    - The wider the key the wider the non-clustered indexes – often with little benefit (although debatable as the non-clustered indexes will cover more queries)
- TIP: Don’t do this! ☺

Optimal Table Structures (cont'd)

Heap is better

- Better base table structure is a HEAP
  - No data row Fragmentation → forwarding rows
  - Could have LOB fragmentation (new LOB_Compaction can help this type of fragmentation)
    - Wastes space in non-clustered indexes by using fixed-RID
    - Scans (due to locking/consistency requirements) can be more expensive!
    - Optimized for space over speed
      - Inserts are slower re: IAM and PFS lookup (reduces the "Swiss cheese problem")
      - Updates can be slower with wide modification – same reason that inserts are slower: record relocation
- TIP: Create HEAPs for staging tables as an interim table for high performance data loading!
- See presentation "High Performance Data Loading" on www.SQLDev.Net for more tips!

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Optimal Table Structures (cont'd)

The right clustered index

- Best base table structure is the RIGHT Clustered Index
  - Cluster on identity column or possibly add one for clustering
  - Cluster on composite key (date, identity) for tables that also have this pattern
  - Key Criteria: Static, Narrow and Unique
  - Effective Hot Spot(s) using Identity (or date, id) or composite key to create multiple (but not random) hot spots – possibly consider partitioning for large tables/high volume OLTP

TIP: If this doesn't exist consider adding a surrogate column solely to cluster on it!

TIP: Make sure to find the RIGHT Clustered index for *your* environment

TIP: Make sure to AUTOMATE check on fragmentation and defragment if/when necessary

Clustering for Performance

- Cluster for internal benefits which lead to:
  - Better insert/update performance re: fewer splits
  - Better Availability as full table maintenance may not be needed
- Reliance on Nonclustered indexes is greater:
  - Faster access to narrow/low selectivity range queries
  - NC Indexes are used in numerous non-obvious ways (multiple NC Indexes can be joined to cover a query)
  - More flexible in the definition (i.e., Indexed Views can include computations, substrings, etc.)
  - New INCLUDE clause can allow wider covering indexes!
  - Non-clustered indexes are easier/faster to rebuild (re: smaller) when they become fragmented
  - Non-clustered indexes are easier to keep less fragmented – i.e., rebuilds with fillfactor has greater benefit since the index row is narrower

Finding the Right Balance

- Start with a minimal number of indexes
  - Clustered Index
  - Primary Key (nonclustered, if not clustered)
  - Unique Keys
- Manually index foreign keys
  - Non-unique indexes
  - Speed up join performance
- Use Database Tuning Advisor
- Manually index based on either:
  - Specific query tuning where DTA didn’t help
  - Query frequency

Finding the Right Balance (cont'd)

SQL Server 2000 resources with GREAT best practices – that STILL apply!

- Support Webcast: *Indexing for Performance: Finding the Right Balance* (recorded 11 June 2004)
  - http://msevents.microsoft.com/CUI/EventDetail.aspx?EventID=1032254503&Culture=en-US
- Support Webcast: *Indexing for Performance: Proper Index Maintenance* (recorded 19 July 2004)
  - http://msevents.microsoft.com/CUI/EventDetail.aspx?EventID=1032256511&Culture=en-US

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Finding the Right Balance (cont'd)

SQL Server 2000 resources with GREAT best practices – that STILL apply!

- Support Webcast: *SQL Server 2000 Profiler: What's New and How to Effectively Use It*

  http://support.microsoft.com/default.aspx?scid=%2Fservicedesks%2Fwebcasts%2Fwc111400%2Fwcblurb111400%2Easp

- Whitepaper: "Index Tuning Wizard for Microsoft SQL Server 2000"
  - http://msdn.microsoft.com/library/en-us/dnsql2k/html/itwforsql.asp?frame=true

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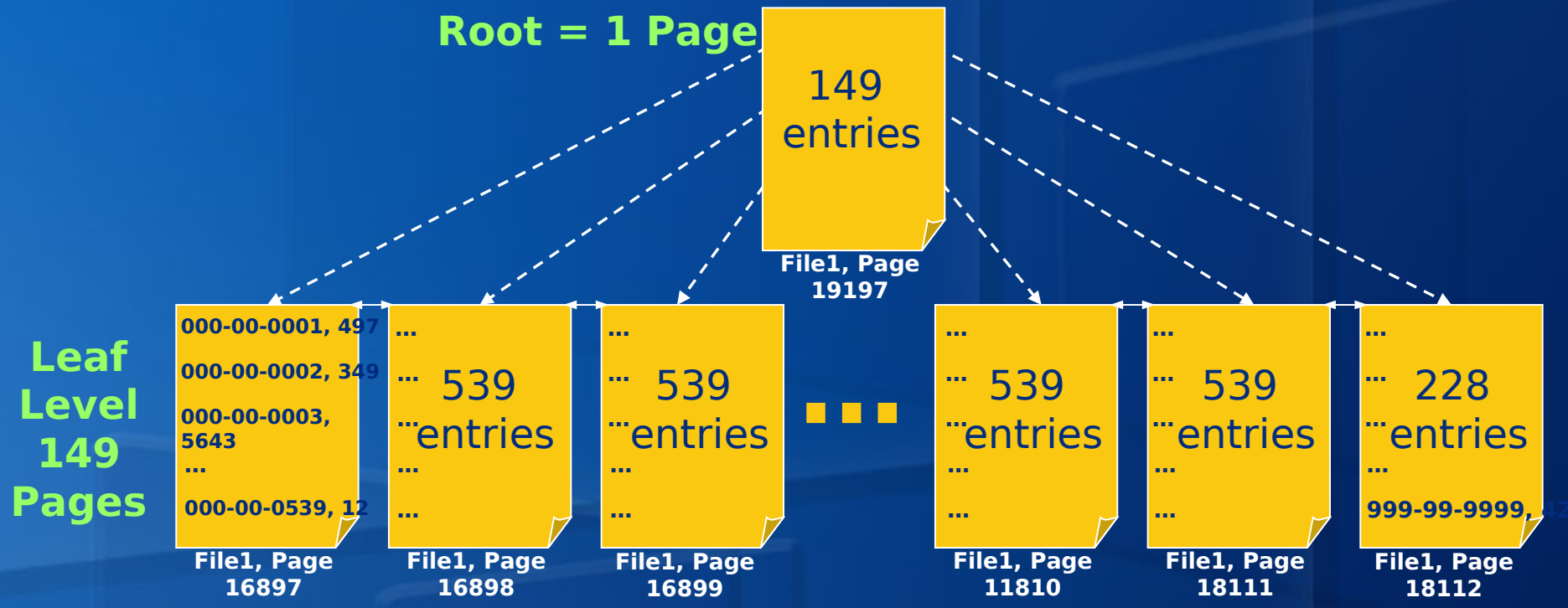
Non-Clustered Indexes

- Internally, non-clustered indexes always store an entry for EVERY row of the table – effectively, they are a “mini” clustered table (of only the index columns)
- If the columns requested in the query are IN the index (regardless of order) then the index COVERs the query
- If queries are narrow this is more likely to happen
- Real-world queries…for example, accessing a large number of tables in a join are typically narrow (the join condition, maybe a search argument and possibly one or two columns in the select list)
- Is it likely that you would ever execute:

SELECT * FROM 8-table-join

What kind of structure is this?



- A non-clustered index on SSN on a table that has a clustered index on EmpID (as we've seen)
- A clustered in on SSN n a table that has ONLY two columns, SSN and EmpID

NOTE: A non-clustered index is EXACTLY the same as a clustered index – but only on the columns that make up the NC index (with the RID

Seems Like…

- Non-clustered indexes are only useful for relatively selective queries…
- What about the following queries?

```
SELECT EmpID, SSN
FROM Employee
WHERE SSN between x and y
```

or

```
SELECT EmpID, SSN
FROM Employee
WHERE EmpID < 10000
```

Think about the access patterns:
- Table Scan (always an option)
- Index Seek w/partial scan
  The nc index on SSN "covers" the query

Think about the access patterns:
- SARG is on clustering key

  The nc index on SSN "covers" the query

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Non-Clustered Indexes
For optimal query performance

- Non-Clustered Indexes are BETTER for low selectivity/range queries because:
  - Non-clustered indexes ARE EXACTLY the same as a clustered index—but narrower
  - If your query only needs columns IN an index then the index is said to “cover” your query
  - No – this does *not* mean that you need to cover every query!!!
  - What it does mean: You can make one or two existing indexes slightly wider and you probably will not hurt INSERT, UPDATE, and DELETE performance and may RADICALLY improve SELECT performance
- Non-Clustered Indexes are narrower and easier to maintain (let ITW/DTA help…)
- Use INCLUDE to create narrower trees, more relevant leaf levels for covering!

Covering an Aggregate

- Increasing Gains with different types of indexes can always be achieved
- Each query can be isolated and tuned as if it were in a sandbox – *not* the goal
- Finding the right balance starts with:
  - Base Indexes (CL, PK, UK, FKs)
  - Capturing a workload, tuning with DTA
  - Prioritizing the queries that are still performing poorly and then choose the optimal level of gain by understanding the trade-offs

Indexing for Aggregations

- Two types of Aggregates:
  Stream and Hash
- Try to Achieve Stream to Minimize Overhead in temp table creation
- Computation of the Aggregate Still Required
- Lots of Users, Contention and/or Minimal Cache can Aggravate the problem!

Aggregate Query

- Member has 10,000 Rows
- Charge has 1,600,000 Rows

```
SELECT c.member_no AS MemberNo,
       sum(c.charge_amt) AS TotalSales
FROM dbo.charge AS c
GROUP BY c.member_no
```

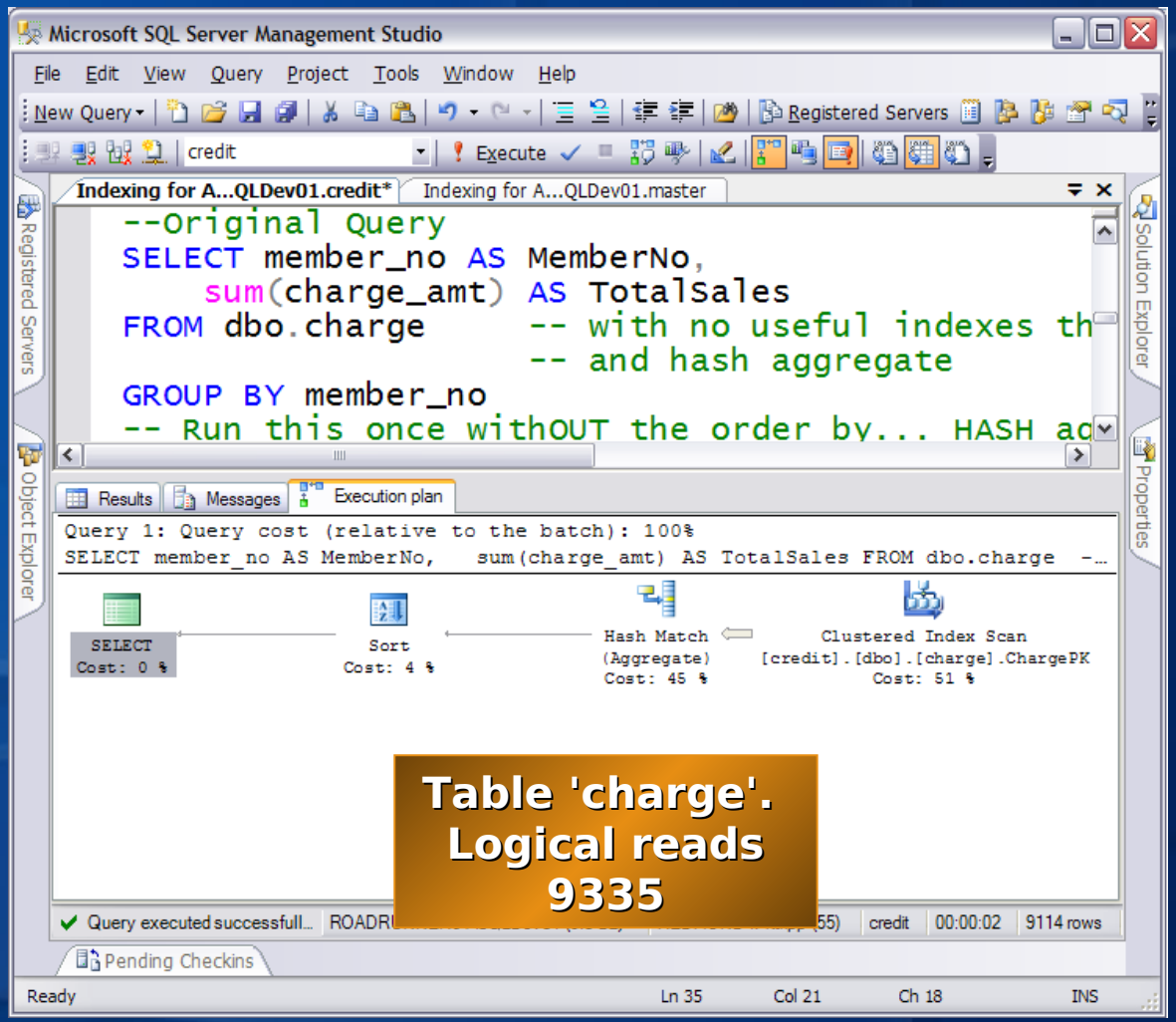
Aggregate Query (cont'd)
Table scan + hash aggregate

```
SELECT c.member_no AS MemberNo,
       sum(c.charge_amt) AS TotalSales
FROM dbo.charge AS c
GROUP BY c.member_no
```

- Table Scan of Charge Table
  - Largest structure to evaluate
  - Worst case scenario
- Worktable created to store intermediate aggregated results – OUT OF ORDER (HASH)
- Data Returned OUT OF ORDER – unless ORDER BY added
- Additional ORDER BY causes another step for SORT – sorting can be expensive!

Worst Case

- Clustered Index Scan
  (table scan)
  1,600,000 rows
- Hash Aggregate
  yields 9,114 rows
  out of order
- Sort
  only has to sort
  9,114 rows instead
  of 1,600,000 rows
- Return Data



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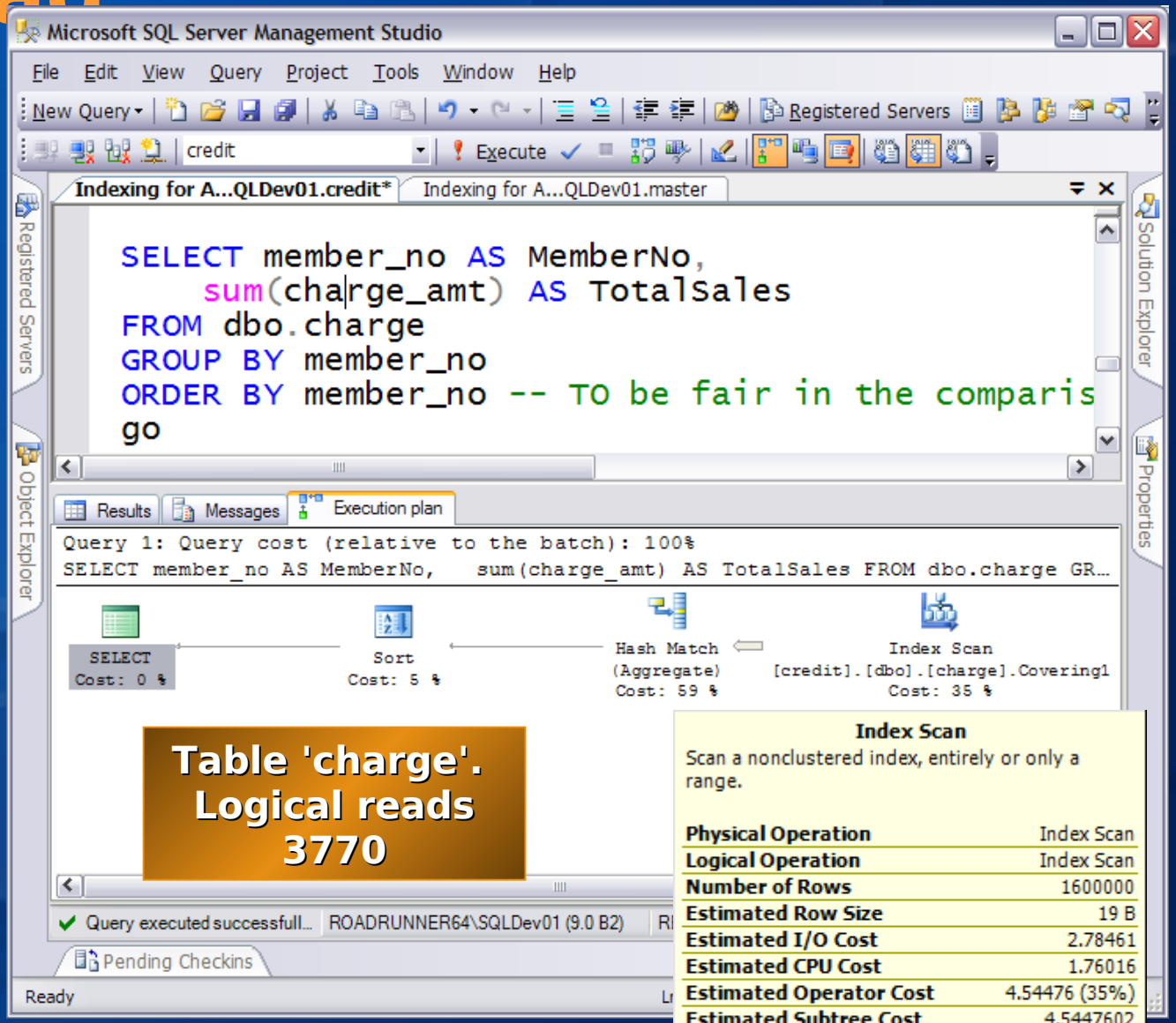
Aggregate Query
Index scan + hash aggregate

```
SELECT c.member_no AS MemberNo,
       sum(c.charge_amt) AS TotalSales
FROM dbo.charge AS c
GROUP BY c.member_no
```

- Out of Order Covering Index on Charge Table
  - Index Exists which is narrower than base table
  - Used instead of table – to cover the query
- Worktable still created to store intermediate aggregated results – OUT OF ORDER (HASH)
- Data Returned OUT OF ORDER – unless ORDER BY added
- Additional ORDER BY causes another step for SORT – sorting can be expensive!

Not as Bad

- COVERING Index Scan
  1,600,000 narrower rows
- Hash Aggregate
  yields 9,114 rows out of order
- Sort
  only has to sort 9,114 rows instead of 1,600,000 rows
- Return Data



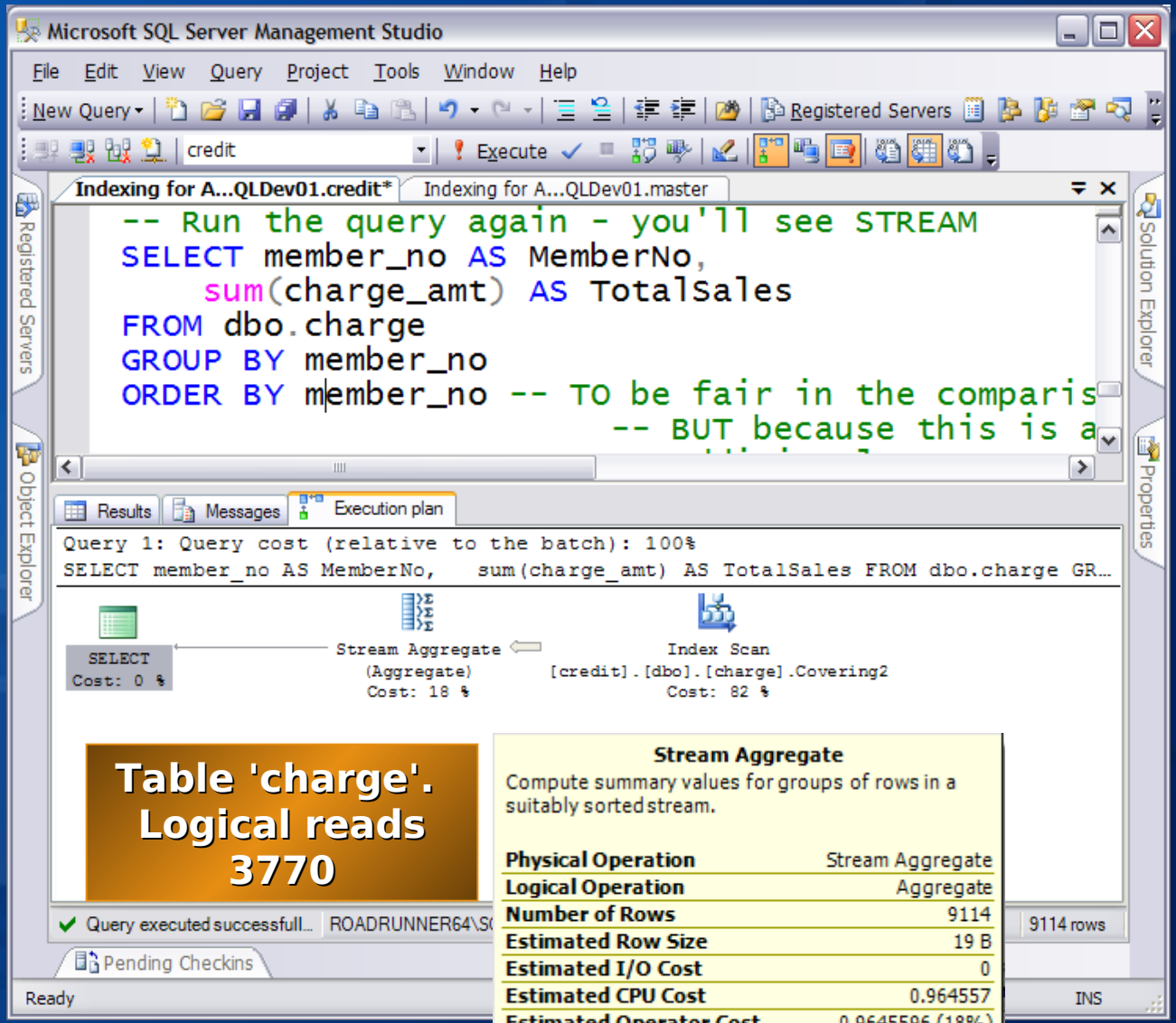
Aggregate Query
Index scan + stream aggregate

```
SELECT c.member_no AS MemberNo,
       sum(c.charge_amt) AS TotalSales
FROM dbo.charge AS c
GROUP BY c.member_no
```

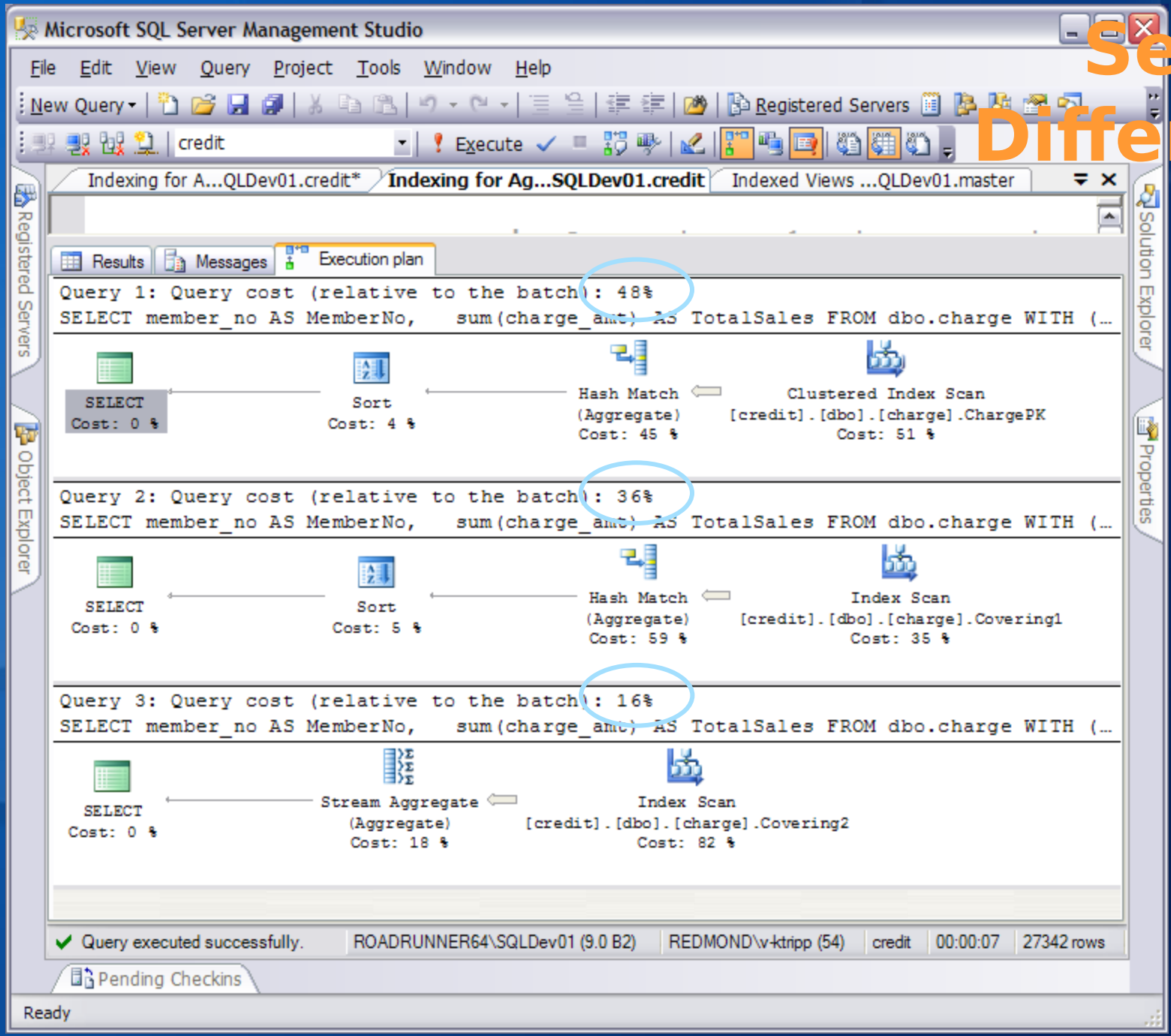
- Covering Index on Charge Table – In ORDER of GROUP BY Clause
  - Index Exists which is narrower than base table
  - Used instead of table – to cover the query
  - Covers the GROUP BY so data is grouped
- Less work to aggregate results IN ORDER
- Data Returned IN ORDER – unless ORDER BY or other joins added
- Adding an ORDER BY identical to the GROUP BY does NOT cause any additional step for sorting!

Much Better!

- COVERING Index Scan 1,600,000 narrower rows
- Stream Aggregate also yields 9,114 rows IN ORDER NO SORT REQUIRED
- Return Data



See the Difference ?



Concerns

- More temp tables
- More contention in tempdb
- Larger tempdb required
- Performance Varies on each execution
- Aggregate needs to be computed

Is there a better way?

Indexed Views!

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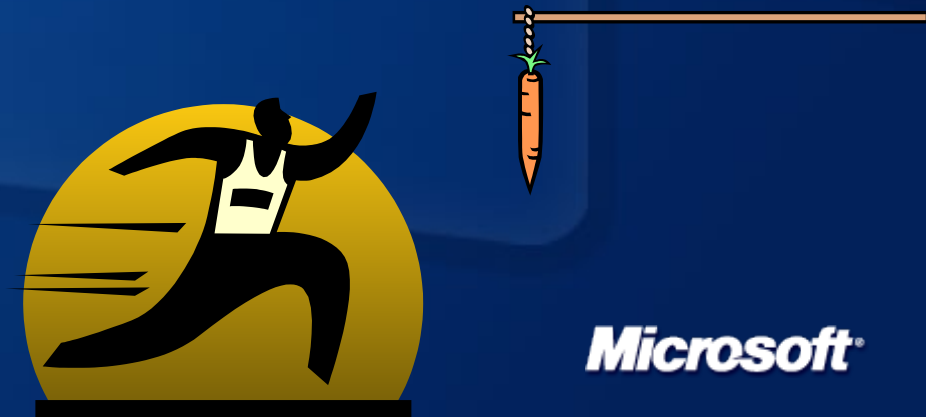
The Punch Line?

What kinds of gains can you get?

Will it be worth it?



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Aggregate Query Indexed view

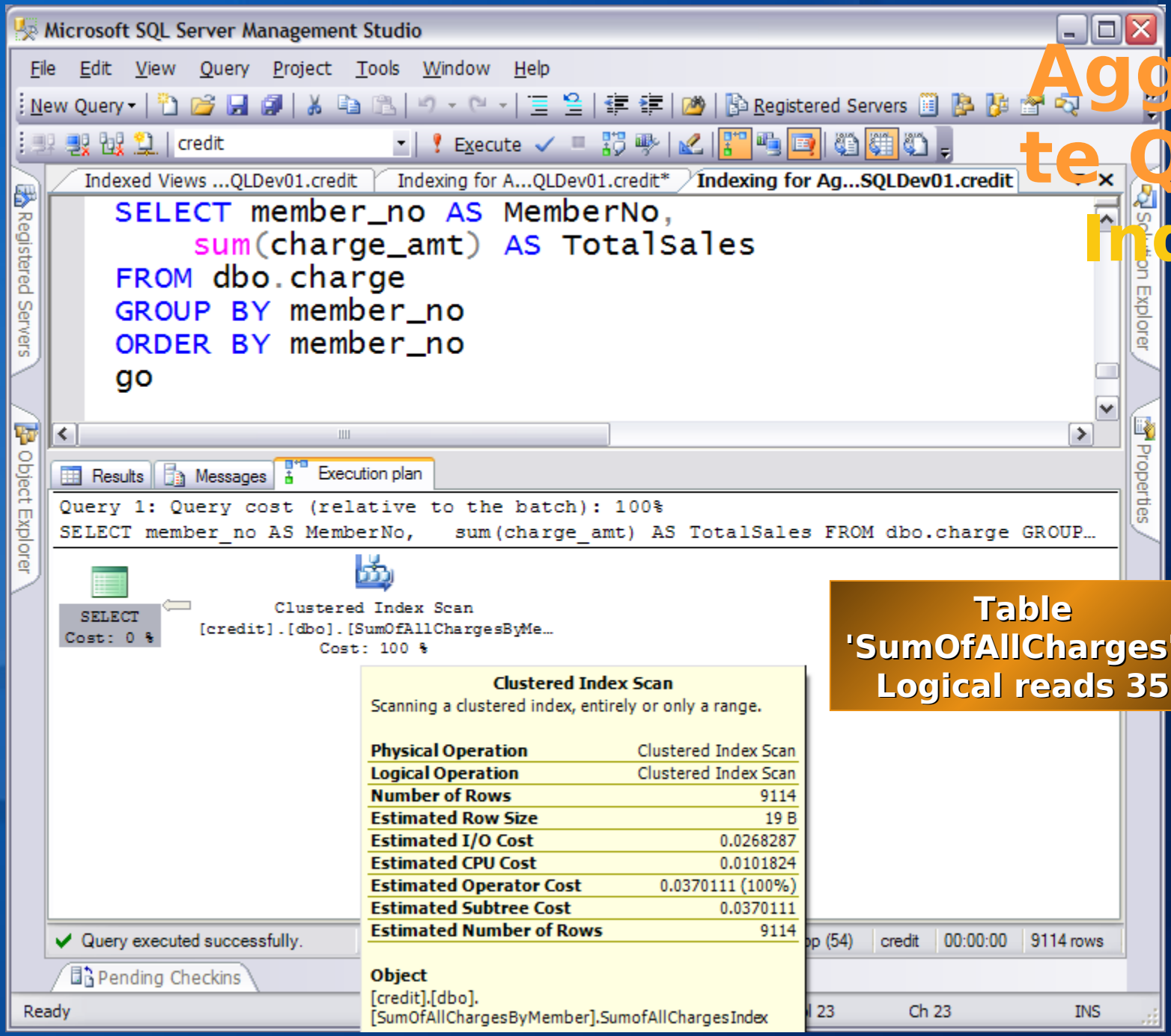
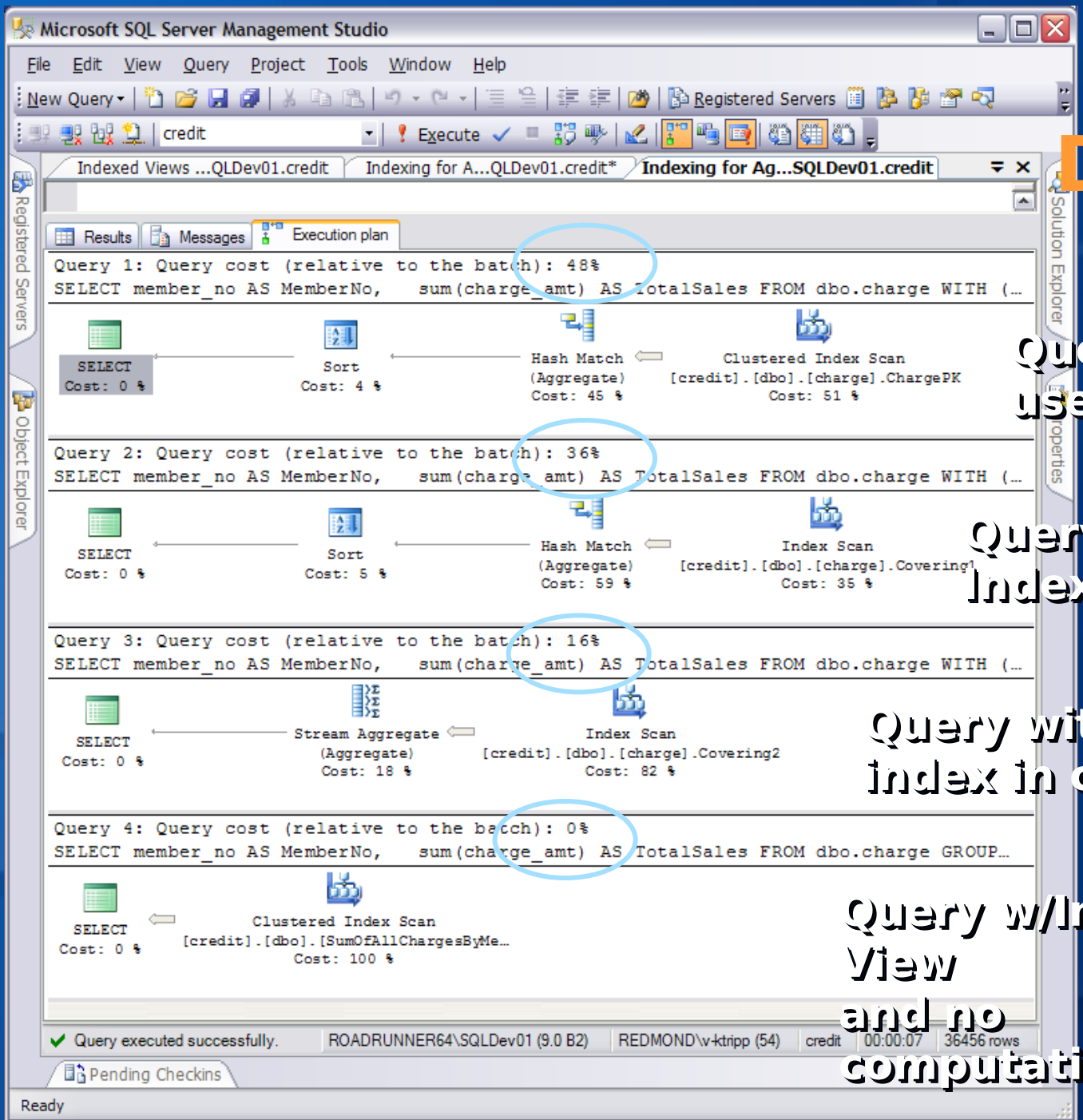


Table 'SumOfAllCharges'. Logical reads 35

See the Difference ?



Query with NO useful indexes

Query with covering index in wrong order

Query with covering index in correct order

Query w/Indexed View and no computations!

Indexed View for Aggregates
Key points

- TempDB access not necessary
- NO worktables are necessary
- Aggregated set should be small but not too small as to create a hot ROW spot of activity (which can create excessive blocking)
  - GROUP BY member_no – probably OK
  - GROUP BY state – too few rows in aggregate
  - GROUP BY country – *avoid* like the plague!
- Performance of data modification statements should be tested

INCLUDE Non-key Columns Compared to Indexed Views

- Indexed Views allow aggregates – adding interesting columns in the leaf level of an index offers “creative covering”
- With new INCLUDE clause, leaf level of index can include non-key columns
- Index key [has been since 7.0] limited to 900 bytes/16 columns – this is to keep tree structure and non-leaf levels optimal/small
- Allows more covering indexes
- Indexed View v. Include – depends on what needs to be in the leaf level

Finding the Right Balance
Index strategies: Summary

- Determine Primary Usage of Table – OLTP vs. OLAP vs. Combo? This determines Clustered Index
- Create Constraints – Primary Key and Alternate/Candidate Keys
- Manually Add Indexes to Foreign Key Constraints
- Capture a Workload(s) and Run through Index Tuning Wizard
- Add additional indexes to help improve SARGs, Joins, Aggregations

Are you done?

NO!

Keeping Performance Optimal

- Write effective queries to help optimizer use indexes
- Make sure statistics are accurate
  - Keep auto update statistics ON
  - Keep auto create statistics ON
- Make sure indexes don’t become overly fragmented
  - Rebuild Table/Index Structures
  - Defrag Table/Index Structures

More details regarding Index Fragmentation and Reindexing in SQL Server 2005 in Session DBA329 after this session!

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Review

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- Keeping performance optimal

Resources

- The SQL Server 2005 Developer Center on msdn

  http://msdn.microsoft.com/SQL/2005/default.aspx
- “SQL Server 2005 Webcasts” contains links for 20+ webcasts
- “SQL Server Hands-On labs” contains links to online virtual lab environments and lab resources
- “SQL Server 2005 Articles” contains sections for different disciplines and links to 25+ articles/whitepapers
- Keep watching the Developer Center, there are new resources every week!

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Resources

- Check out www.SQLskills.com for information about upcoming **SQL Immersion** events, useful links and event scripts.
- Read my blog: http://www.SQLskills.com/Blogs/Kimberly/
- Subscribe to SQLskills: http://www.SQLskills.com/login.aspx
- MSPress: *SQL Server 2000 High Availability*
  *A*uthors: Allan Hirt with Cathan Cook, Kimberly L. Tripp and Frank McBath
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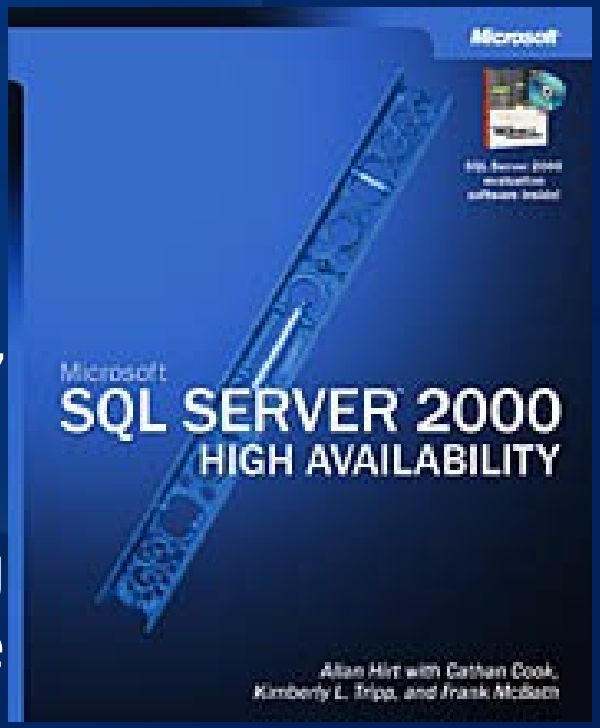

questions?

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Community Resources

- Microsoft Community Resources
  http://www.microsoft.com/communities/default.mspx
- Non-Microsoft Community Resources
  http://www.microsoft.com/communities/related/default.mspx
- Newsgroups
  Converse online with Microsoft Newsgroups, including Worldwide
  http://www.microsoft.com/communities/newsgroups/default.mspx
- User Groups
  Meet and learn with your peers
  http://www.microsoft.com/communities/usergroups/default.mspx
- Attend a free chat
  http://www.microsoft.com/communities/chats/default.mspx
- Attend a free web cast
  http://www.microsoft.com/usa/webcasts/default.asp
- Most Valuable Professional (MVP)

Microsoft

Microsoft Learning Resources:

Get ready for Microsoft Visual Studio 2005 and Microsoft SQL Server 2005 with free Assessments and E-Learning, and a chance to win a laptop, GPS, and more

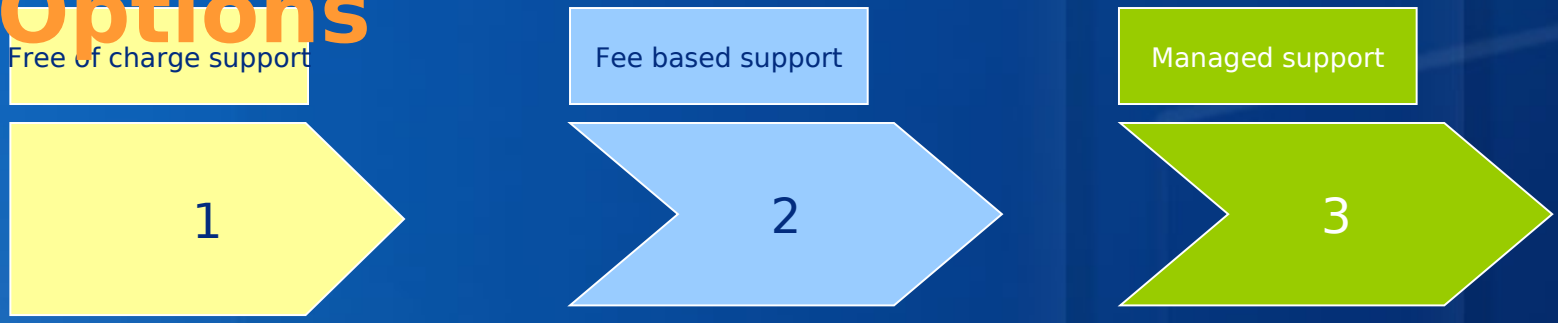
- Click here to access free Microsoft Learning Assessments http://www.microsoft.com/learning/assessment/ind/default.asp
- To access free Microsoft Learning E-Learning visit http://www.microsoft.com/learning/access and reference the promotional code **9185-TECHED-6650**.

Special offers on Microsoft Certification from Microsoft Learning

- Click here to take advantage of these special offers: http://www.microsoft.com/learning/mcp/

Microsoft

The Microsoft Guide to Support Options



Self Support

- Knowledge Base
- Microsoft Newsgroups
- Support Webcasts

Assisted Support

- Email Support
- Phone Support
- Advisory Services
  - Remotely delivered, hourly fee–based, consultative support option

Contract-based Support

- Microsoft Premier Support
  - Provides premium level support and a designated Account Manager
- Microsoft Essential Support
  - Prepackaged support options including phone and online access to a pool of skilled Technical Account Specialists
- Microsoft Partner Advantage
  - Partner Advantage provides technology partners the best response times and highest level of problem resolution support

Resources:

Microsoft Support Website: http://support.microsoft.com
Microsoft TechNet program: http://technet.microsoft.com
Microsoft MSDN program: http://msdn.micrososft.com

Microsoft


All attendees who submit a session feedback form within 120 minutes after the session ends will have the chance to win an MPx220 With Windows Mobile™ Software.
Added Bonus!! This year you will also have the chance to win one of eight Xbox 360s! We will be giving away two a day – one for the morning sessions, and one for the afternoon sessions.
Good luck!
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